SEMATECH

Accelerating the next technology revolution

Update From The SEMATECH EUV Mask Infrastructure Initiative

October 17, 2011

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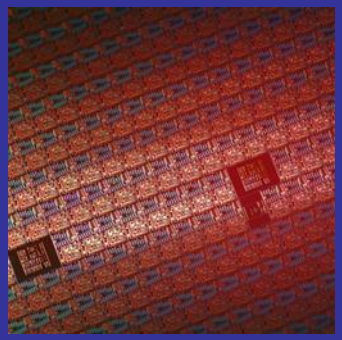

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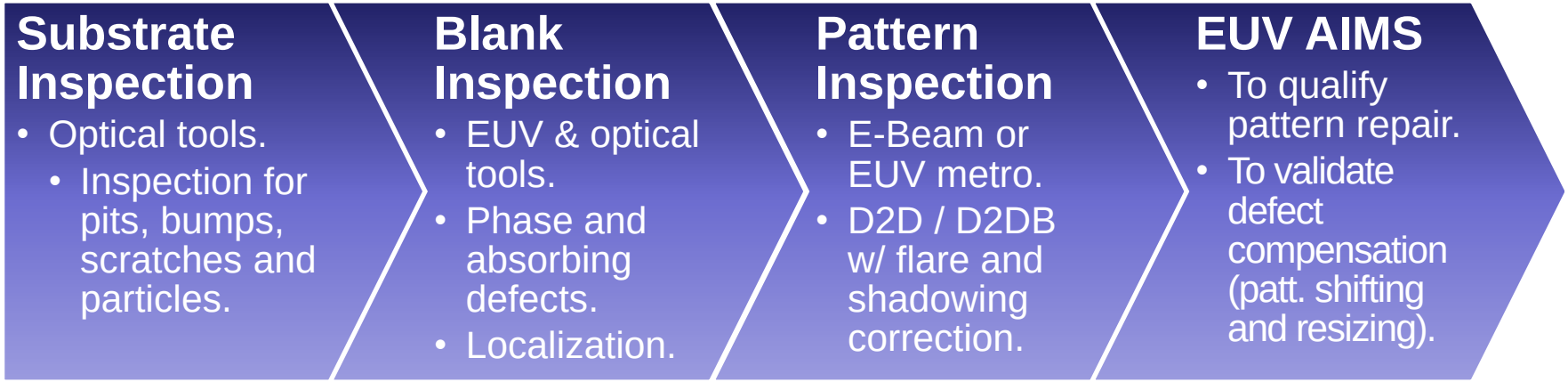
EUV Mask Infrastructure (EMI) Program

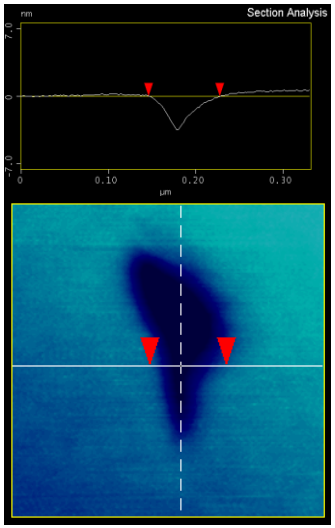
- The EMI initiative is a SEMATECH program to support and selectively develop EUV mask metrology equipment.
- Printable defects have to be eliminated, avoided or repaired.
- Defect inspection, compensation and review are main focus areas. The SEMATECH – Zeiss AIMS™ EUV project has started.

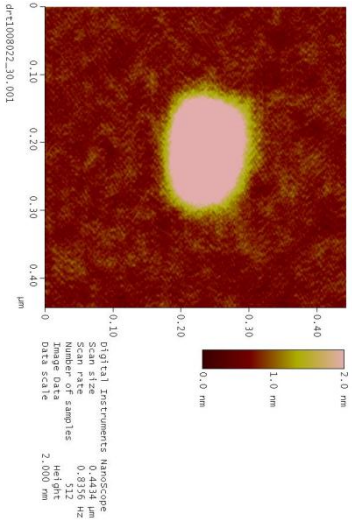


- Lasertec & SMT developed equipment available.
- Two suppliers engaged. EMI efforts are on-hold.
- SMT test vehicles are being developed.
- Multiple suppliers actively engaged.
- EMI is in the KLA 7xx Prod. Readiness Partnership.
- SMT – Zeiss collaboration project started.

Typical Defect Images

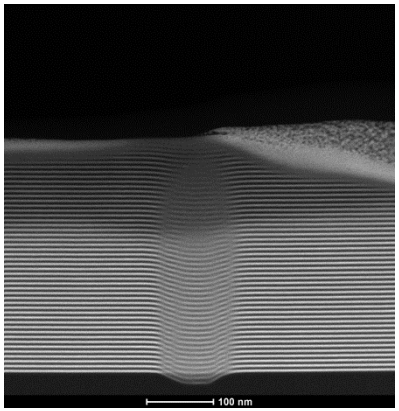
Example Substrate AFMs

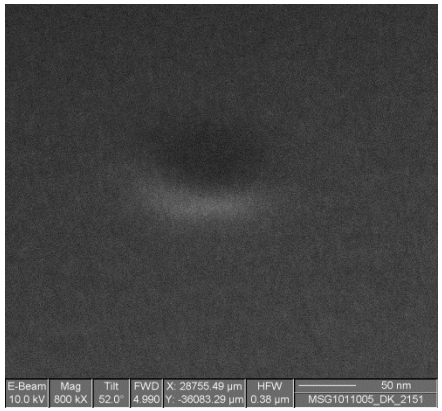




Blank Phase Pit-Defect

5.3nm high x 51nm FWHM

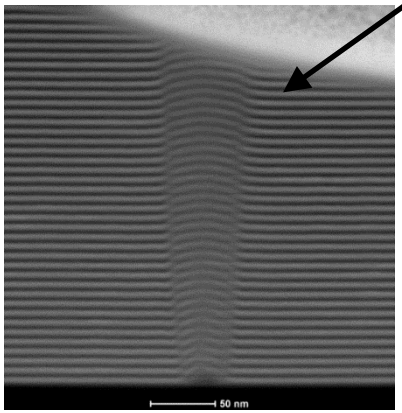


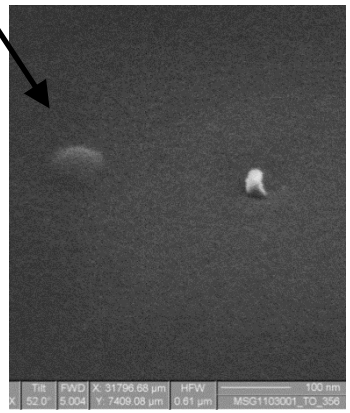


SMTM4-2151

Blank Phase Bump Defect

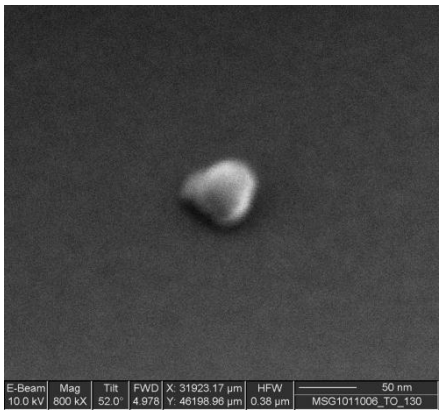
~8nm high x 62nm FWHM

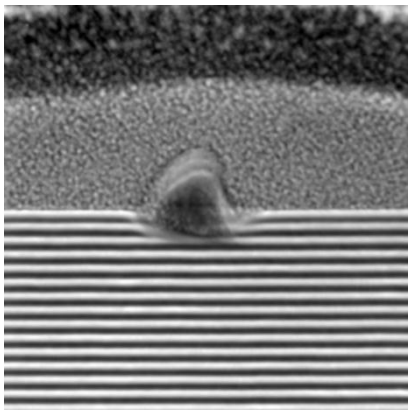




Particle Examples

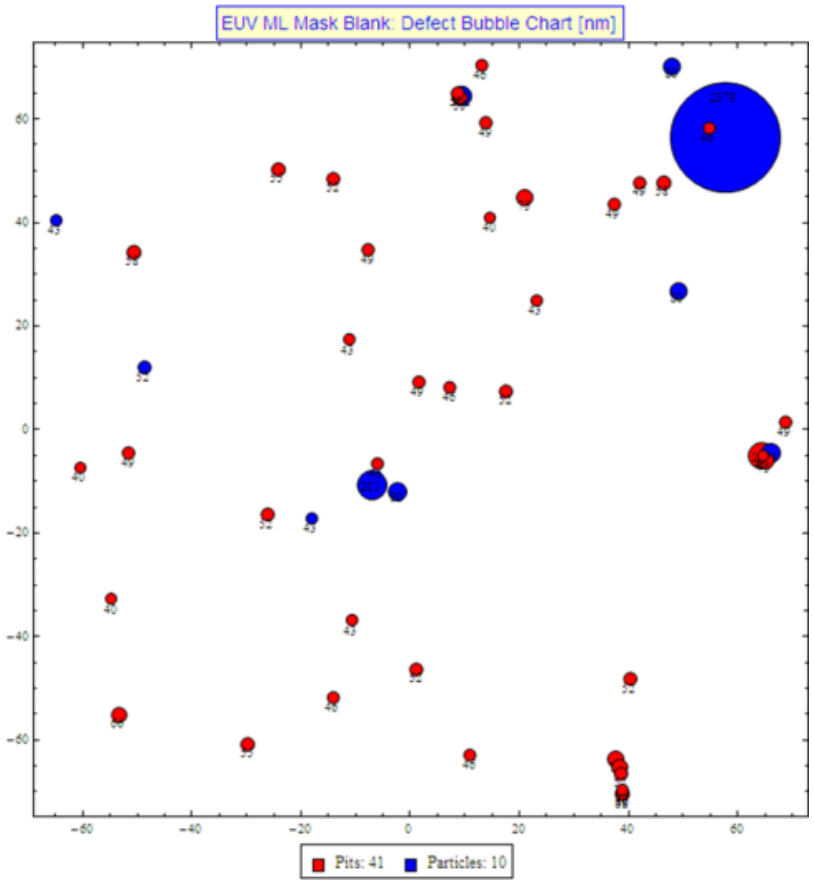
~50nm ~30nm



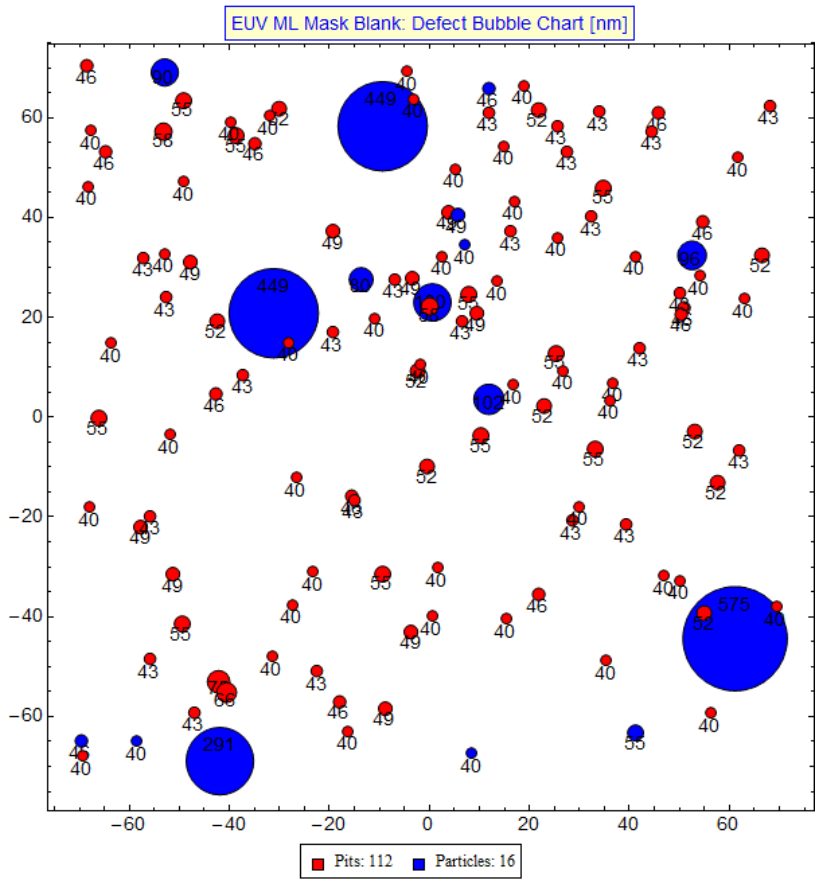


State Of The Art On Mask Blank Defects

- Champion ML Blank
  - 41 Pits & 10 Particles



- Typical ML Blank
  - 112 Pits &16 Particles

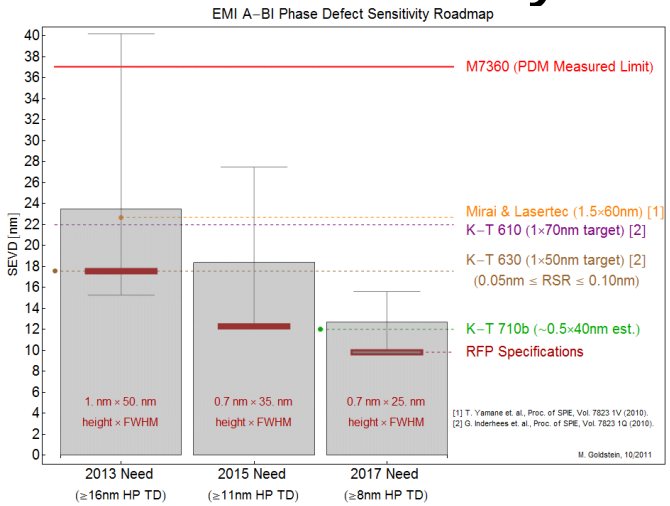


- Needed A-BI capabilities: phase defects, amplitude defects, defect locations.

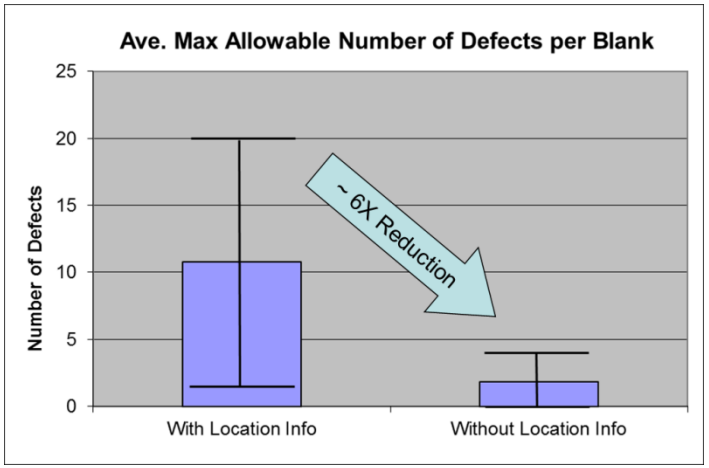
Quartz substrates.

Actinic Mask Blank Inspection Requirements

- Phase Sensitivity



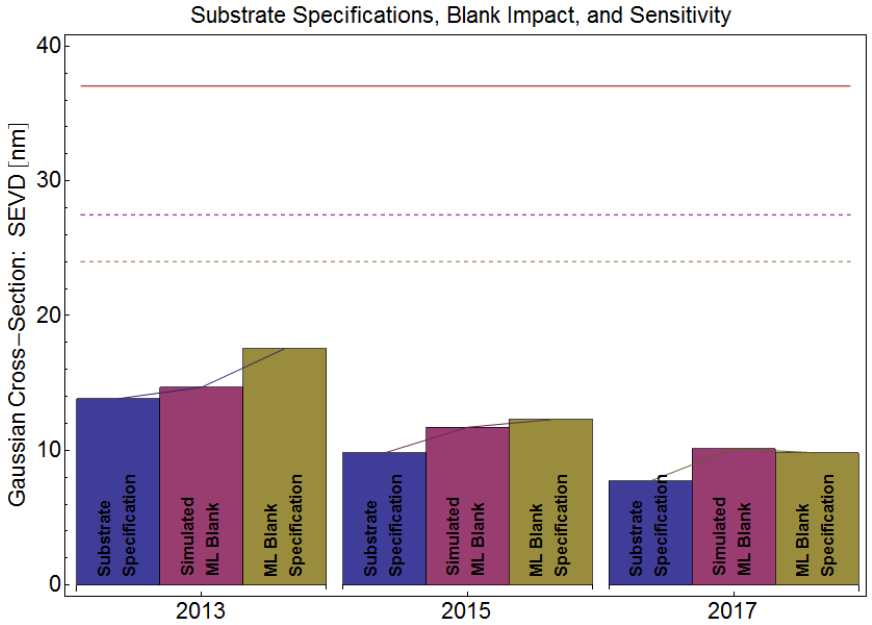
- Defect Localization

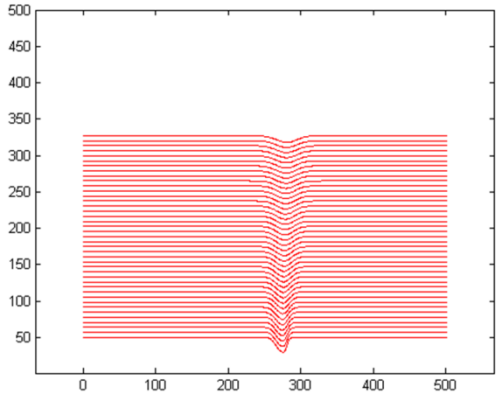


- Defect size and density requirements are accelerating about as fast as the industry's current improvement rate.
- Defect localization and pattern shifting is a potential game changer. Required for any successful A-BI equipment.
- Amplitude Defects
  - Less frequent then phase defects, however they are present on every mask.
  - An industry spec roadmap for amplitude defects needs to be developed.
  - SMT modeling and programmed amplitude-defect mask development started.

Substrate Requirements & Defect Growth Modeling

- Our preliminary substrate-defect roadmap appears to be overly conservative, however sensitivity requirements are likely below the capability of existing inspection tools.
  - Missed substrate defects can be picked up at ML blank inspection.
  - The cost and cycle time impact might (or might not) be acceptable.
- Defect growth models are being calibrated so we can work back from the ML blank specs to obtain substrate specs.

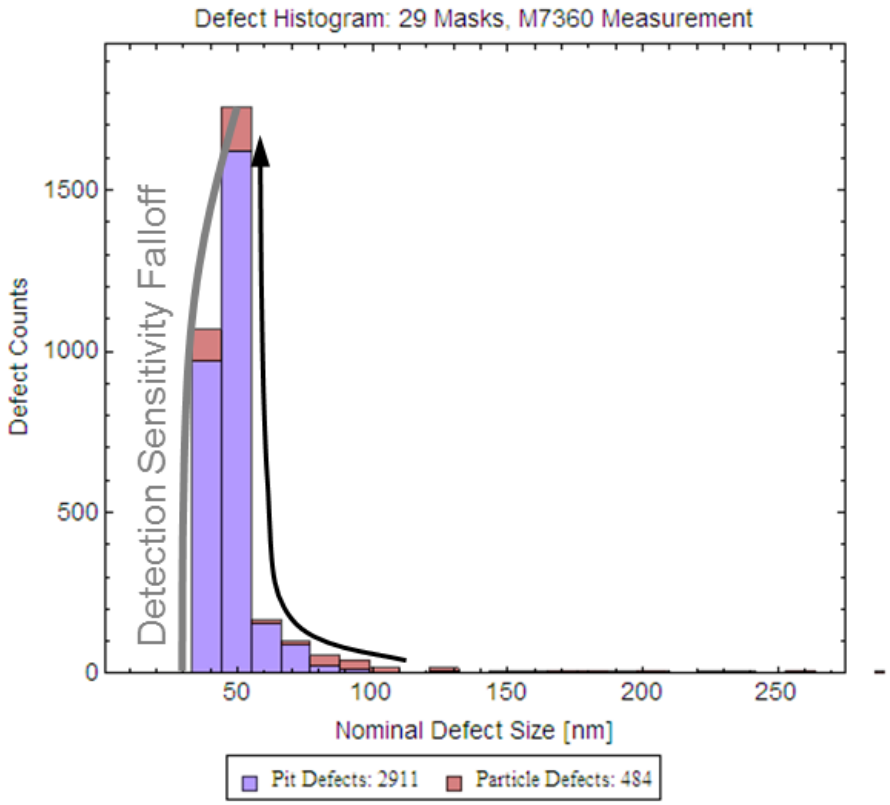


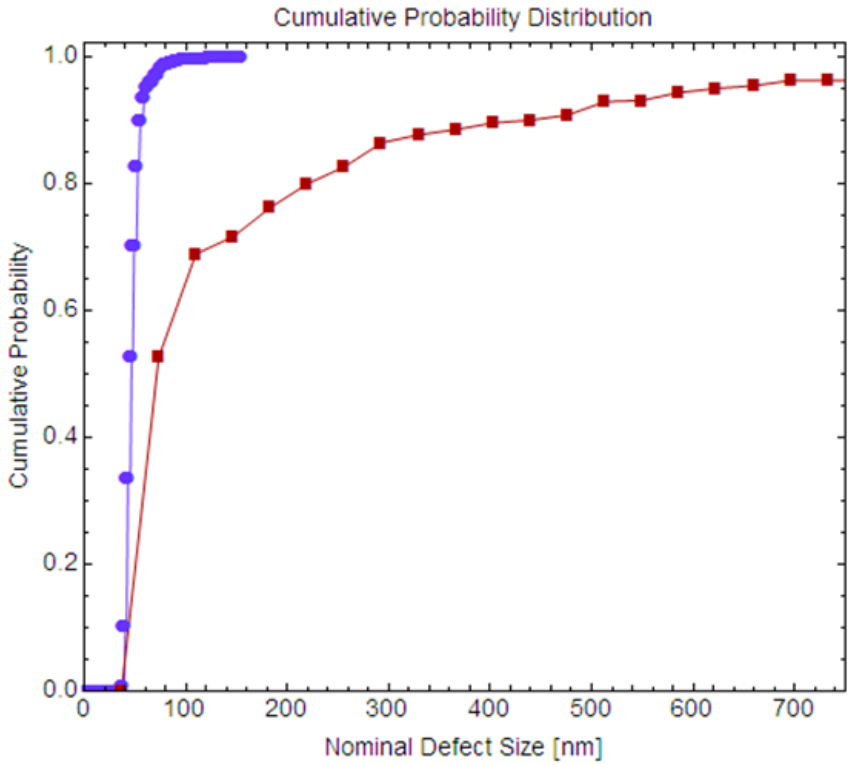


Visit poster: J. Harris-Jones, V. Jindal, C.C. Lin, T. Charkraborty, R. Teki, and H. Kwon, "Failure analysis and defect characterization for EUV mask blanks."

ML Blank Defect Density and Yield Marathon
How do we stand today?

- 29 EUV Mask Blanks
  - Lasertec M7360
  - 2,911 Pits (~100/mask)
  - 484 particles (~17/mask)
- Cumulative blank yield.*
  - 10% yield at >45nm process sensitivity, 50% for 73nm, 75% for a 175nm threshold.



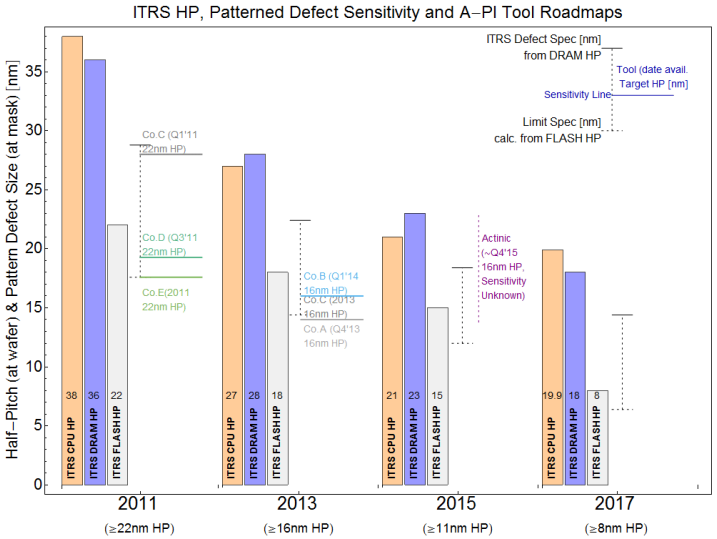


* Without localization and pattern shifting.

Pattern Mask Inspection (Actinic & E-Beam)

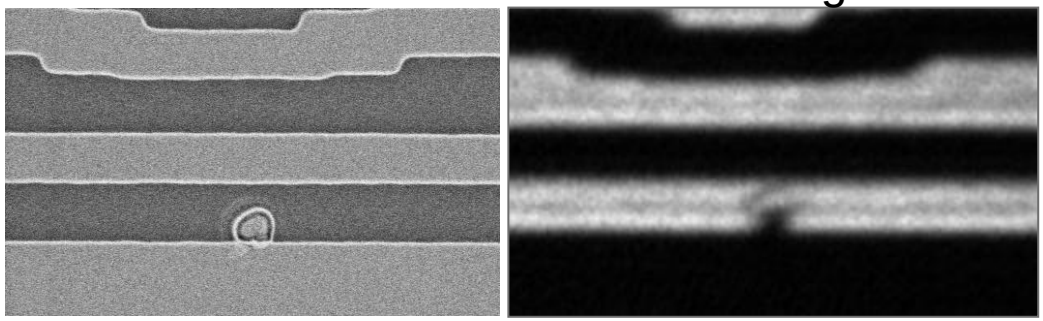
- There is healthy competition between optical, e-beam and actinic patterned mask inspection suppliers. SEMATECH is participating in and monitoring industry efforts.

- There are questions at sub-16nm nodes about interference stack parameters, aperture, pupil fills, CRA, and defect types. SEMATECH and LBNL are developing SHARP (the SMT High-NA Actinic Reticle Review Project) to investigate blank and pattern mask patterns.



Pattern SEM*

AIT Image*

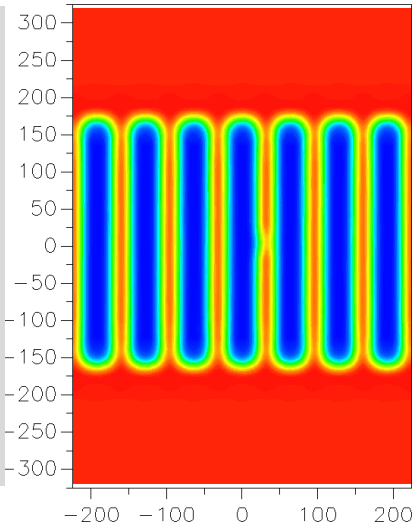


* I. Mochi, K.A. Goldberg, B. LaFontain, A. Tchikoulaeva, C. Holfeld, "Actinic imageing of native and programmed defects on a full-field mask," Proc. of SPIE 7636-45, 76361A, 2010.

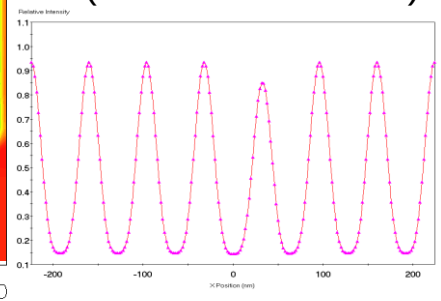
AIMS™ EUV Usage

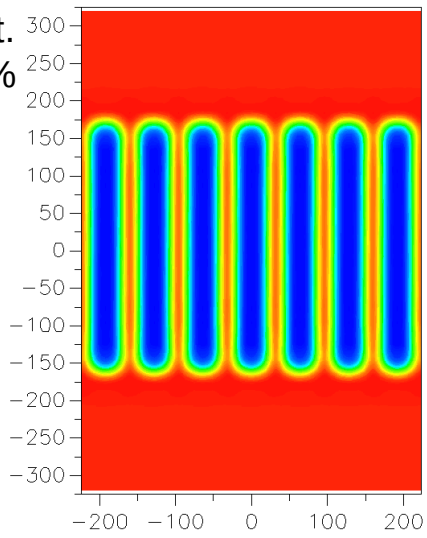
- Mask aerial image review can be used to check defect printability, avoidance and repair.
  - Some defects are mush less important than others. But these still have to be reviewed.
  - Absorber defects found by e-Beam or EUV pattern mask inspection can be repaired, and checked by aerial image review.
  - Localized blank defects can be covered with absorber by shifting the entire mask pattern, and checked with actinic inspection or AIMS.

Simple Scalar Model
RCWA Analysis Needed

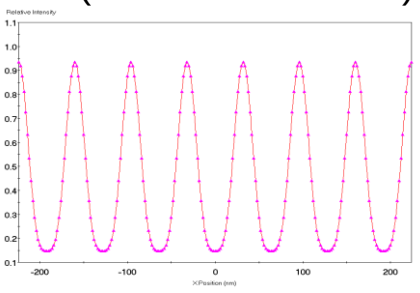


Exposed Amplitude Defect.
50nm Wide (at mask), 20% per pass absorptance.
⇨ ~5% CD Error
(at 35.8% threshold).



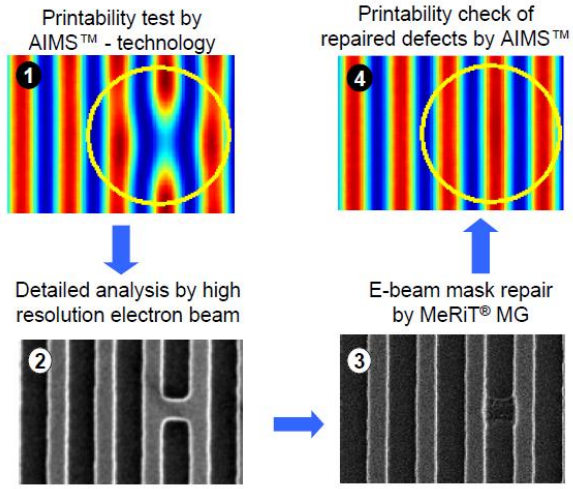


Fully Covered Defect.
50nm Wide (at mask), 20% per pass absorptance.
⇨ 32nm L/S target
(at 35.8% threshold).

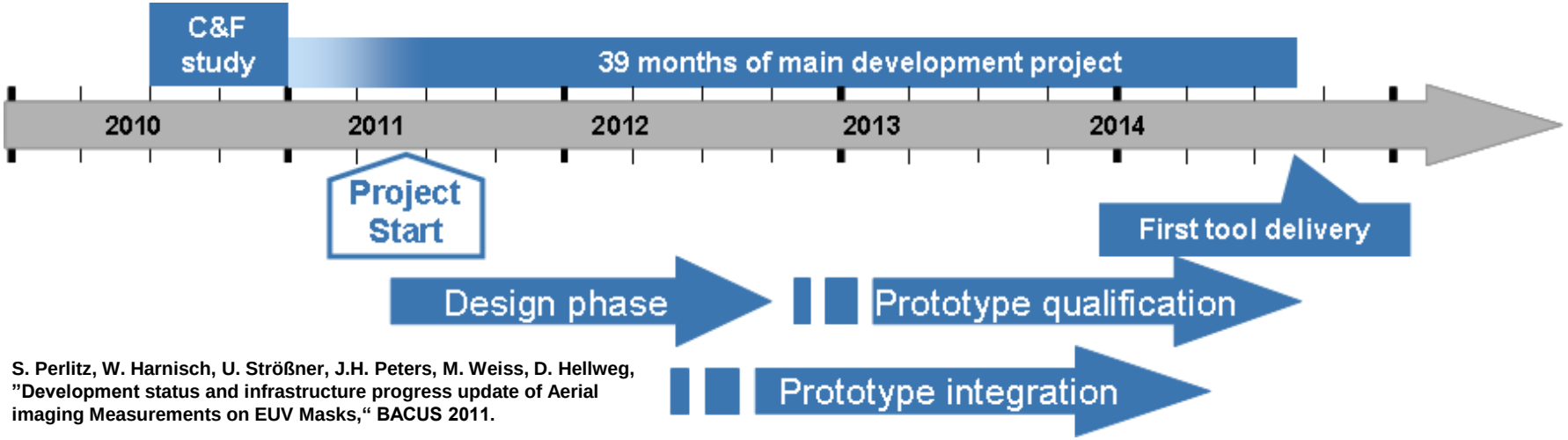


SEMATECH – Zeiss AIMS™ EUV Collaboration

- Zeiss AIMS™ EUV project started (05/2011).
- Four EMI members are participating.



D.Hellweg, J.Ruoff, A.Herkommer, H.Feldmann, M.Ringel, U.Strößner, S.Perlitz, W.Harnisch, "Actinic aerial image review of EUV masks," Proc of SPIE 7969-15 (2011).



S. Perlitz, W. Harnisch, U. Strößner, J.H. Peters, M. Weiss, D. Hellweg, "Development status and infrastructure progress update of Aerial imaging Measurements on EUV Masks," BACUS 2011.

AIMS™ is a trademark of Carl Zeiss SMT AG.

Conclusions

- Mask inspection and review tools are critically important for the successful HVM introduction of EUV lithography.
- Multiple equipment suppliers are engaged in competitive development for mask blank and pattern mask inspection. Zeiss has begun development of the AIMS™ EUV tool.
- Potential gaps:
  - At substrate inspection, tools exist but sub-sensitivity defects are going to be picked up at blank inspection. There will be a cost /cycle-time impact from this.
  - At blank inspection, phase-defect sensitivity roadmaps are consistent with industry needs. Amplitude-defect sensitivity is at risk of bleeding into pattern mask yield. Defect localization and pattern shifting is a potential game changer for blank yield.
  - At pattern mask inspection, e-beam and actinic solutions are competing. If blank defects are missed then actinic pattern inspection and EUV AIMS could be needed for absorber shape and resizing compensation.